# Refuge-in-a-Bag Approach for Sustainable Management of Virulent Soybean Aphids in the Field

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## Introduction

The soybean aphid (*Aphis glycines* Hemiptera: Aphididae) is a major pest of soybean in the Midwest. An unmanaged aphid outbreak has the potential to reduce yield by up to 40 percent. During the summer, aphids rapidly reproduce, resulting in exponential population growth.

Foliar-applied insecticides are the most widely used management strategy for protecting yield loss from soybean aphids. Using varieties carrying aphid resistance genes (i.e. *Rag*) also is an effective means to suppress aphids. However, virulent aphid biotypes can colonize resistant plants. Use of only aphid-resistant plants throughout a landscape could lead to the fixation of virulence in the soybean aphid population. Inclusion of an aphid-susceptible refuge can be an effective strategy to preserve the efficacy of *Rag* genes. Blended seed mixtures, or refuge-in-a-bag, is an approach used in corn, but is not yet available in soybean.

A field experiment was conducted to test whether a refuge-in-a-bag approach can protect yield while maintaining a population of soybean aphids.

## Materials and Methods

The effects of host plant resistance (*Rag*), inclusion of a susceptible refuge, and foliar insecticide treatment on aphid population and yield was evaluated. Insecticide treatment was included to estimate yield loss from aphids and genetic differences between resistant and susceptible plants. The experiment was designed as a split-plot randomized complete block design with four replicate blocks. Four refuge mixes (main plot) were treated or left untreated with a foliar pyrethroid insecticide (split plot).

Aphid-resistant variety LD12-15805Ra (carrying *Rag1 + Rag2*) and its susceptible isoline LD12-15838R were used. Both varieties were resistant to glyphosate. Aphid-susceptible (S): aphid-resistant (R) mixes were prepared before planting as follows:
100 percent S:0 percent R, 25 percent S:75 percent R, 10 percent S:90 percent R, and 0 percent S:100 percent R (hereafter mixes are referred to by susceptible percentage only). Mixes were planted in plots 100 ft x 80 ft (~ 0.18 acres) at 140,000 seeds/acre May 16.

Aphids were scouted weekly from June through September. When aphid-free split plots had 10 aphids/plant, these were sprayed with Warrior II CS August 7 and September 7. The number of aphids was converted to cumulative aphid days (CAD) as a way to estimate the seasonal exposure of plants to aphids. Soybean seeds were harvested October 20. Yields were estimated and compared between treatments.

## Results and Discussion

*Effect of refuge.* Aphids colonized plants from late July through September (Figure 1). Compared with the 100 percent S treatment, plots that included resistant plants experienced significantly lower aphid populations (CAD), which increased as the susceptible proportion increased (Figures 1, 2A). However, only one

treatment was significantly different—the 100 percent S treatment experienced higher CAD than all other refuge treatments. All treatments that included aphid-resistant seeds were not significantly different from each other (Figure 2A). These results indicate inclusion of a susceptible refuge did not affect the capacity of *Rag* genes to limit aphid outbreaks, but did maintain an aphid population consistent with refuge requirements.

Soybean aphid populations reached the economic injury level (EIL, ~5,500 CAD) in the 100 percent S treatment (Figure 2A), but the EIL was not reached in any of the treatments with aphid-resistant seeds in the mixture. Despite reaching populations that were expected to reduce yield, there was no significant differences in yield among any of the seed mixes. The lack of yield loss may be explained by the timing of aphid outbreak, which occurred in late August to early September (Figure 1). By that time, plants were at full seed set (R6). In Iowa, insecticide treatments are not recommended for controlling soybean aphids past mid-seed set (R5.5) as there is little evidence foliar insecticides provide yield protection from aphids past this growth stage.

*Effect of insecticides*. A foliar insecticide treatment to estimate differences in yield due to soybean aphids and from genetic differences between the resistant and susceptible varieties was included. Insecticides were applied multiple times to keep the plants free of aphids. The insecticide treatment had an overall significant effect on soybean aphids (Figures 1, 2A), suggesting this pyrethroid insecticide can prevent outbreaks for this population of aphids.

A significant interaction was found between refuge and insecticide for CAD (Figure 2A), indicating insecticides had different impacts on soybean aphids within the different refuge treatments. Insecticides reduced aphid populations in the 100 percent S treatment fourfold. However, because the aphid populations were so low in the mixtures with aphid-resistant seeds, the impact of the insecticides was not statistically significant.

When averaged across all refuge treatments, plots receiving an insecticide yielded nearly two bushels/acre higher than untreated plots (Figure 2B). However, because of the low aphid populations experienced at the Northwest Research Farm in 2017, it is suspected the yield loss was not caused by soybean aphids but rather by some other insect(s) controlled by the insecticides. Although insecticides had an overall effect on yield, the aphid-free treatment results provide evidence aphid-resistance genes *Rag1* and *Rag2* do not cause yield drag (Figure 2B).

Overall, data suggests aphid-resistant soybeans blended with aphid-susceptible plants could serve as a refuge and still be effective for suppressing aphids in the field. Thus, refuge-in-a-bag could be a viable resistance management strategy for soybean aphid.

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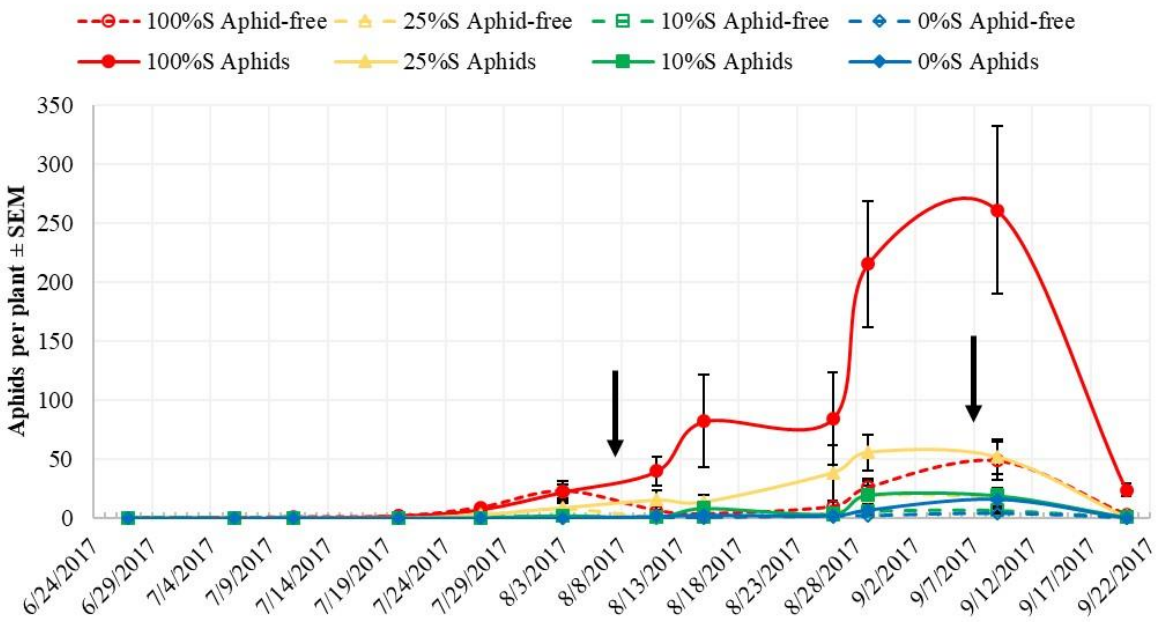


**Figure 1. Aphid populations on mixes of aphid-susceptible (S) and aphid-resistant soybean varieties compared with pure stands of each variety. Solid lines represent plots that were not treated with foliar insecticides while dotted lines represent plots that were treated. Arrows indicate date of insecticide application. Plots that contained aphid-resistant seed in the mixture had lower aphid populations than the 100 percent aphid-susceptible seed.**

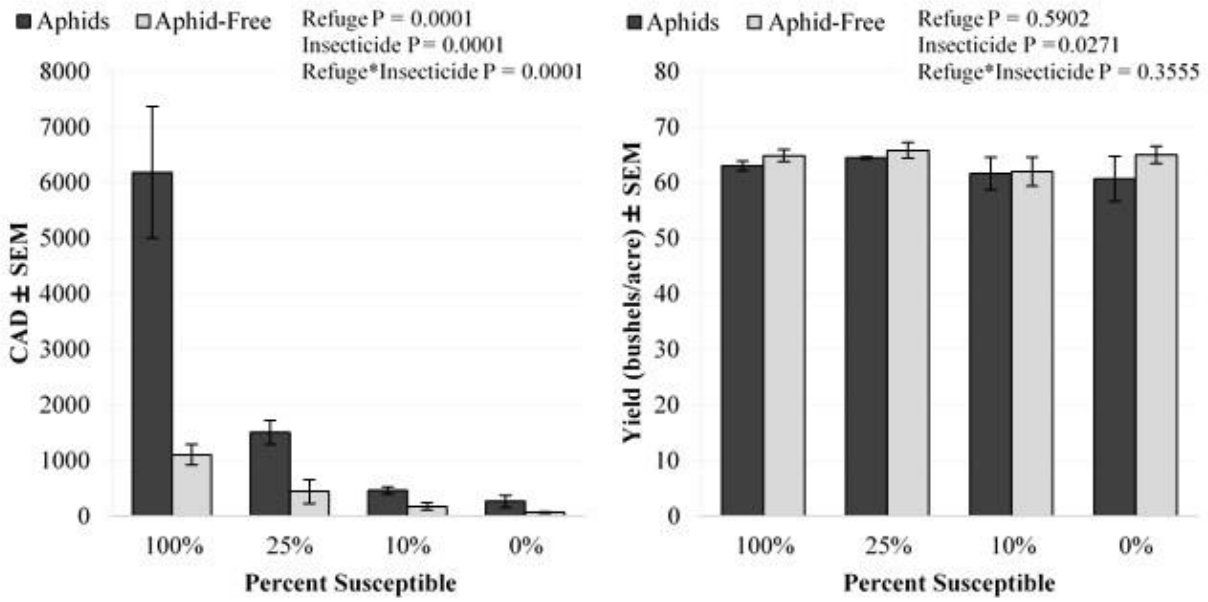


**Figure 2. Summary of the seasonal exposure of plants to soybean aphids (A), cumulative aphid days (CAD), and yield (B) at the ISU Northwest Research Farm in 2017. The four seed mixes are summarized on the x-axes based on the amount of aphid-susceptible soybean (i.e. refuge). Refuge, insecticide, and the interaction had a significant ($P < 0.05$) effect on aphids (CAD). Insecticide treatment had a significant ($P < 0.05$) effect on yield.**